

# ROCK STRENGTH/SLOPE STABILITY

# Notes on Piteau Report concerning...

"Geotechnical Assessments and Preliminary Slope Design Alternatives", by Alan Stewart.

Dec, 1988

- p.5 folds w/in pE plunge  $\approx$  ?
- p.7 Further definition of Structural Domains may become necessary during mining when more exposures are avail.
- p.8 Structural attitude Determined Domains; other parameters were secondary
- Joints - 3 main sets recognized w/ 3 subsidiary or subordinate sets
- A) Foliation joints; (pE rx), STRIKE-NW, DIP-SW
  - B) Joint Set A; Present in pE, Ttp, Tgtp,
    - in pE these strike NW, DIP STEEPLY NE & are present for short Dist.
    - in intrusive Rocks these STRIKE NW, DIP BOTH NE & SW @  $> 80^\circ$
    - CONTINUOUS OVER AT LEAST ONE Bench (20'?)
  - C) Joint set B; Present in all 3 rock types
    - in pE these strike NE, DIP STEEPLY NW and are relatively short compared to Foliation joints & slightly MORE CONTINUOUS THAN JOINT SET A in pE.
    - in intrusive Rocks STRIKE NE & DIP BOTH NW & SE and ARE AS CONTINUOUS AND AS WELL DEVELOPED AS sets of Joint set A

## RQD (Rock Quality Designations)

- A) RQD tends to improve w/ depth
- B) Tgtp more competent than Ttp

### UNCONFINED COMPRESSIVE STRENGTH (UCS)

- UCS of Ttp & Ttp RANGES FROM 12,000 TO 30,000 PSI
- UCS of pE  $\perp$  foliation " " 30,000 - 40,000, || foliation is 7,000 - 10,000
- Overall, these rocks ARE CONSIDERED "hard to very hard"
- Further work NOT REQUIRED AT THIS TIME.
- DIRECT SHEAR TESTING OF JOINTS MAY BE REQUIRED IN THE FUTURE

### HYDROGEOLOGY

Apparently no problem in pit

### SLOPE STABILITY ANALYSES & SLOPE DESIGN

NO COMMENT.

Basically saying no problem, but may be like square marbles:  
& Also Assuming dry slopes (well drained). (I think  
in-pit H<sub>2</sub>O needs to be evaluated much more before  
Assuming no problems due to H<sub>2</sub>O.

SAMPLE LIST

① TRACHYTE PORPHYRY (SULFIDE)

a) DH 69 - 267.8 → 268.4  
285.3 → 285.9

b) DH 62 - 495 → 495.7  
513 → 513.6  
535.5 → 536

② TRACHYTIC PORPHYRY (OXIDE)

a) DH 62 331.5 → 332.2  
411.5 → 411.9

③ QTZ. TRACHYTE PORPHYRY (SULFIDE)

a) DH 81-28 968'  
970'  
975  
976  
977

④ QTZ. TRACHYTE PORPHYRY (OXIDE)

a) DH 62 73 → 73.6  
91.5 → 92

⑤ PRECAMBRIAN SCHIST

a) DH 63 283 → 283.5  
326 → 326.6  
406 → 406.6

b) DH 64 401.2 → 401.8  
428.4 → 429

SKELETON FROM 1987  
HQ/NQ CORE TAKEN  
BY AL STEWART OF  
PITEAU FOR FURTHER  
TESTWORK RELATED  
TO PIT SLOPE STABILITY  
FOR THE GILTEGE  
EXPANSION PROJECT

J.B.  
12/8/88



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## DESCRIPTION OF CORE LOGGING TECHNIQUE

Prepared by  
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JUNE, 1985

## DESCRIPTION OF CORE LOGGING TECHNIQUE

The basic parameters measured from the rock core are as follows:

1. Core recovery
2. Rock hardness
3. Degree of fracturing (breakage)
4. Degree of weathering
5. Core size

It is noteworthy that the best data on core competency can be collected by the drill inspector at the drill site before the core becomes broken or data lost from excessive handling, splitting, or drying out.

The data on the various parameters may be tabulated on appropriate recording forms and presented graphically for specific boreholes on geological sections or plans.

A detailed description of each of the parameters recorded is given in the following:

### 1. CORE RECOVERY AND RQD

Core recovery is expressed as a percentage of the total length drilled for each core run which is marked by wooden blocks in the core boxes. Recovery gives an indication of the quality of the ground being drilled and the general competency of the rock. Low recovery may also be indicative of faults.

### 2. RQD (ROCK QUALITY DESIGNATION)

The RQD is defined as the percentage of core in each run in which the spacing between natural fractures is greater than four (4) inches (10 cm).

### 3. HARDNESS

A simple scheme for classifying soil or rock according to its consistency or hardness is given below. Using this scheme, a reasonable first estimate of the unconfined compressive strength ( $q_u$ ) of the material may be made. Classifications are based on simple mechanical tests which can be easily performed in the field. By the use of fingers, a pocket knife and geologic pick and with a minimum amount of experience, the complete range of classifications can be established in the field.

#### QUALITATIVE & QUANTITATIVE EXPRESSIONS FOR CONSISTENCY OF COHESIVE SOIL AND ROCK\*

HARDNESS	CONSISTENCY	FIELD IDENTIFICATION	APPROXIMATE RANGE OF UNCONFINED COMPRESSIVE STRENGTH	
			Kg/cm <sup>2</sup> (Approx Tons/ft <sup>2</sup> )	p.s.i.
S1	very soft	Easily penetrated several inches by fist.	<0.25	<3.5
S2	soft	Easily penetrated several inches by thumb.	0.25 - 0.5	3.5 - 7
S3	firm	Can be penetrated several inches by thumb with moderate effort.	0.5 - 1.0	7 - 14
S4	stiff	Readily indented by thumb but penetrated only with great effort.	1.0 - 2.0	14 - 28
S5	very stiff	Readily indented by thumbnail.	2.0 - 4.0	28 - 56
S6	hard	Indented with difficulty by thumbnail.	>4.0	>56
R0	extremely soft	Indented by thumbnail.	2.0 - 7.0	28 - 100
R1	very soft rock	Crumbles under firm blows with point of geological pick; can be peeled by a pocket knife.	7.0 - 70	100 - 1,000
R2	soft rock	Can be peeled by a pocket knife with difficulty; shallow indentations made by firm blow of geological pick.	70 - 280	1,000 - 4,000
R3	average rock	Cannot be scraped or peeled with a pocket knife; specimen can be fractured with single firm blow of hammer end of geological pick.	280 - 560	4,000 - 8,000
R4	hard rock	Specimen requires more than one blow with hammer end of geological pick to fracture it.	560 - 1,120	8,000 - 16,000
R5	very hard rock	Specimen requires many blows of hammer end of geological pick to fracture it.	1,120 - 2,240	16,000 - 32,000
R6	extremely hard rock	Specimen can only be chipped with geologic pick.	>2,240	>32,000

\* Modified Rock Hardness Classification

- S1 to S6 Modified after Terzaghi, K. and Peck, R.B., 1967. "Soil Mechanics in Engineering Practice, 2nd Edition, John Wiley and Sons Inc., New York. p.30.
- R1 to R5 Modified after Piteau, D.R., 1970. "Geological Factors Significant to the Stability of Slopes Cut in Rock" in Planning Open Pit Mines, Van Rensburg Ed. Aug. 29-Sept. 4, 1970. Balkema. p.51 and 68.

#### 4. DEGREE OF BREAKAGE

Degree of Breakage is a visual and thus somewhat subjective estimation of the quality of the rock in terms of the number of fractures or breaks. General categories, numerical equivalents and qualifying descriptions are given below.

CATEGORY	NUMERICAL EQUIVALENT	MEAN SPACING OF BREAKS OR DIAMETER OF FRAGMENTS (in.)	QUALITY DESCRIPTIONS
A-	1		Mostly fault gouge with/without minor rock fragments
A	2	$\leq \frac{1}{2}$	Gouge and crushed rock
A+	3		Crushed rock with/without minor gouge
B-	4	$\frac{1}{2}$ to 2	Crushed rock - no gouge
B	5		Crushed rock - diameter of pieces $\leq 2$ in.
B+	6		Broken rock - fracture spacing $\leq 2$ in.
C-	7		Mean spacing 2 to 3 in.
C	8	2 - 4	Mean spacing 3 in.
C+	9		Mean spacing 3 to 4 in.
D-	10		Mean spacing 4 to 6 in.
D	11	4 - 8	Mean spacing 6 in.
D+	12		Mean spacing 6 to 8 in.
E- <del>10</del>	13		Mean spacing 8 to 12 in.
E	14	$> 8$	Mean spacing 12 to 14 in.
E+	15		Mean spacing $> 24$ in.

NOTE: Care should be taken to identify all fault/shear zones (Category A). However, for other Degrees of Breakage, the category should be averaged over a length of three (3) metres.

## 5. DEGREE OF WEATHERING

The degree of weathering or oxidation of the rock core is used to define the upper boundary of unweathered bedrock and to delineate faults and other zones of intense weathering. The degree of weathering is estimated visually to give a qualitative feel for this parameter. The classification for degree of weathering is as follows:

- A - intensely oxidized or weathered.
- B - moderately oxidized or weathered.
- C - mildly oxidized or weathered (on joints only).
- D - fresh and unweathered.

## 6. CORE SIZE

Core size has a direct effect on the quality of core recovered. It is generally recognized that larger diameter core will give better core recovery and a better sample of the geological structures. Accordingly, a record of the core size is kept in conjunction with the core competency study to consider these aspects.

## 7. JOINT FREQUENCY

The number of natural joints or fractures in each core run is used to calculate the joint frequency. In sedimentary rocks, the number of bedding joints/m and number of cross joints/m are recorded separately.

# GEOTECHNICAL CORE LOG

[illegible]

INTERNATIONAL SOCIETY FOR ROCK MECHANICS

COMMISSION ON  
STANDARDIZATION OF LABORATORY AND FIELD TESTS

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SUGGESTED METHODS FOR DETERMINING THE UNIAXIAL  
COMPRESSIVE STRENGTH OF ROCK MATERIALS AND THE  
POINT LOAD STRENGTH INDEX

COMMITTEE ON LABORATORY TESTS  
DOCUMENT No. 1

FINAL DRAFT: October 1972

## PART 2 SUGGESTED METHOD FOR DETERMINING THE POINT LOAD STRENGTH INDEX

### *Scope*

1. This test is intended as a method for measuring the strength of rock specimens in the field, and uses portable equipment. Specimens in the form of either rock core (the 'diametral' and 'axial' tests) or of irregular lumps (the 'irregular lump' test) are broken by application of a concentrated load using a pair of conical platens. A Point-Load Strength Index  $I_p$  (50) is obtained and may be used for rock strength classification.

### *Apparatus*

2. The testing machine incorporates a loading system (comprizing for example, a loading frame, pump, ram and platens), a system for measuring the load  $P$  required to break the specimen, and a system for measuring the distance  $D$  between the two platen contact points. Its essential features are the following:

(a) The loading system should be adjustable to accept and test available rock specimens, for example in the size range 25-100 mm for which a loading capacity up to 50 kN is commonly required. A quick-retracting ram helps to minimise delay between tests. Ram friction should be low so as not to impair the accuracy of load measurement.

(b) Spherically truncated conical platens (Fig. 1) are used to transmit load to the specimen. The 60° cone and 5 mm radius spherical truncation should meet tangentially, and the platens should be hardened so that they remain undamaged during testing. The platens should be accurately aligned so that each is coaxial with the other, and the machine should be rigid to ensure that the platens remain aligned during testing. No spherical seat or other non-rigid component is permitted in the loading system.

(c) The load-measuring system should indicate the failure load  $P$  to an accuracy of  $\pm 2\%$  irrespective of the strength of specimen tested. It should incorporate a maximum indicating device so that the reading is retained and can be recorded after specimen failure. It should be resistant to hydraulic shock and vibration so that the accuracy of readings is maintained during testing.

(d) The distance-measuring system should indicate the distance  $D$  between platen-contact points to an accuracy of  $\pm 0.5$  mm. It should be designed to allow zero check and adjustment and should be robust so that its accuracy is maintained during testing.

### *Procedure*

3. (a) Rocks to be classified are first divided into «units», each of which is considered on the basis of a preliminary inspection to have uniform strength. One sample of rock containing sufficient material for the required number of test specimens is then selected from each unit. Samples in the form of core are preferred for accurate classification. For routine testing, specimens should be tested at close to their natural water content. For precise classification and comparison samples should be stored at  $20^\circ\text{C} \pm 2^\circ\text{C}$  and  $50 \pm 5\%$  humidity for 5-6 days prior to testing.

(b) *The diametral test.* Core specimens with length/diameter ratio greater than 1.4 are suitable for diametral testing. Preferably ten or more tests per sample are required depending on the available quantity of core and on the uniformity of rock in the sample. The specimen is inserted in the test machine and the platens closed to make contact along a core diameter, ensuring that the distance  $L$  between the contact point and the nearest free end is at least  $0.7 D$  where  $D$  is the core diameter (Fig. 2 (a)). The distance  $D$  is recorded and the load increased to failure. The failure load  $P$  is recorded and the procedure repeated for the remaining specimens in the sample.

(c) *The axial test.* Core specimens with length/diameter ratio of  $1.1 \pm 0.05$  should be used (Fig. 2 (b)). Long pieces of core can be tested diametrically to produce suitable lengths for subsequent axial testing. Preferably ten or more specimens per sample are required, depending on the available quantity of core and on the uniformity of rock in the sample. The specimen is inserted in the test machine and the platens closed to make contact along the core axis. The distance  $D$  is recorded and the load increased to failure. The failure load  $P$  is recorded and the procedure repeated for the remaining tests in the sample.

(d) *The irregular lump test.* Rock lumps with typical diameter approximately 50 mm and with a ratio of longest to shortest diameter of between 1.0 and 1.4 are selected (Fig. 2) (c) and trimmed using any convenient technique. At least twenty lumps should be tested per sample. Each lump is inserted in the testing machine and the platens closed to make contact along the longest diameter of the lump, away from edges and corners. The distance  $D$  is recorded and the load increased to failure. The load  $P$  is recorded and the procedure repeated for the remaining test in the sample.

(e) *Anisotropic rock.* With rock that is bedded, schistose or otherwise shows observable anisotropy, tests should be made in both weakest and strongest directions. When testing horizontally bedded core, for example, diametral tests will normally give a set of lower bound strength values, i.e. the strength perpendicular to planes of weakness. Care should be taken to ensure that loading is strictly along and perpendicular to the weakness planes. The spacing of diametral tests should be adjusted to ensure that the resulting pieces can later be used for axial testing, noting that the platen separation in the axial test is measured perpendicular to the weakness planes and not necessarily axial to the core. A similar procedure may be followed when testing irregular lumps.

### Calculations

4. (a) The Point-Load Strength Index  $I_p$  is calculated as the ratio  $P/D^2$ .

(b) For classification the index  $I_p(50)$  should be used, obtained from  $I_p$  by correcting this value to a reference diameter of 50 mm using the correction chart given in Fig. 3.

(c) The median value may be found from a set of test results by systematically deleting highest and lowest values until only two remain. The average of these is the required median value.

(d) In diametral testing, where the core diameter  $D$  is effectively constant, the median failure load  $P$  may first be found, then the index applicable to this load calculated and the size correction applied. In axial and irregular lump testing, however, the index for each test must first be obtained and corrected for size. The median value of these corrected results is then computed.

(e) The Strength Anisotropy Index  $I_s(50)$  may be computed as the ratio of corrected median strength indexes for tests perpendicular and parallel to planes of weakness.  $I_s(50)$  assumes values close to 1.0 for isotropic rocks, and higher values when the rock is anisotropic.

### *Reporting of results*

5. Results for diametral tests, axial tests and irregular lump tests perpendicular and parallel to planes of weakness should be tabulated separately. The report should contain the following information for each sample tested:

(a) Sample number and location, also its water content condition, and storage history. If possible numerical values for both water content and saturation should be given. The orientation and nature of any weakness planes present in the rock should be described.

(b) A tabulation of failure load  $P$  and platen separation  $D$  for each test.

(c) Computed values of  $I_s$  and  $I_s(50)$  for each test. These computed values can be omitted in the case of diametral test results, but the median value of failure load  $P$  should be reported.

(d) Median values for  $I_s(50)$  parallel and perpendicular to planes of weakness, together with the computed strength anisotropy index  $I_s(50)$ .

### *Notes*

6. This test is intended as a simple procedure for field classification of rock materials, and when necessary the recommended procedures can be modified to overcome practical limitations. Such modifications to procedure should however be clearly stated in the report.

7. Point-load strength is closely correlated with the results of uniaxial compression and other strength tests. An approximate conversion Uniaxial Compressive Strength =  $24 \times I_s(50)$  can be used (BROCH, E and FRANKLIN, J. A. The Point-Load Strength Test. Trans, Inst. Min. Metall., 1972).

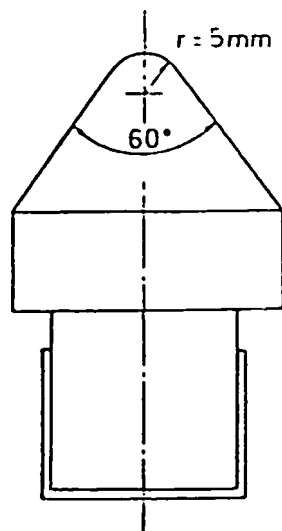
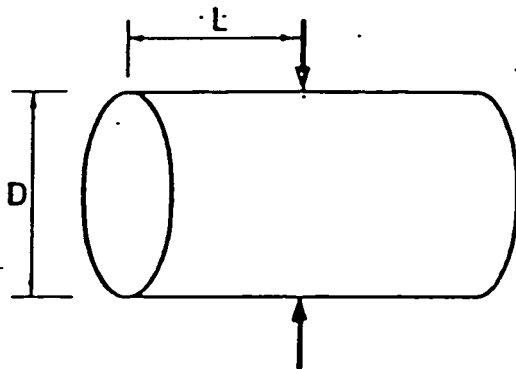
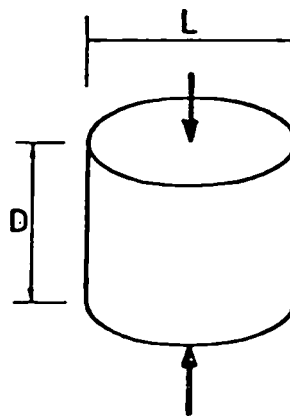


Fig. 1 — Platen dimensions



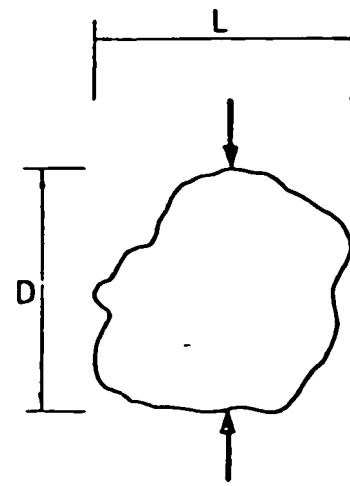
$$L > 0.7 D$$

Fig. 2 (a)  
Diametral test



$$\frac{D}{L} = 1.1 \pm 0.05$$

Fig. 2 (b)  
Axial test

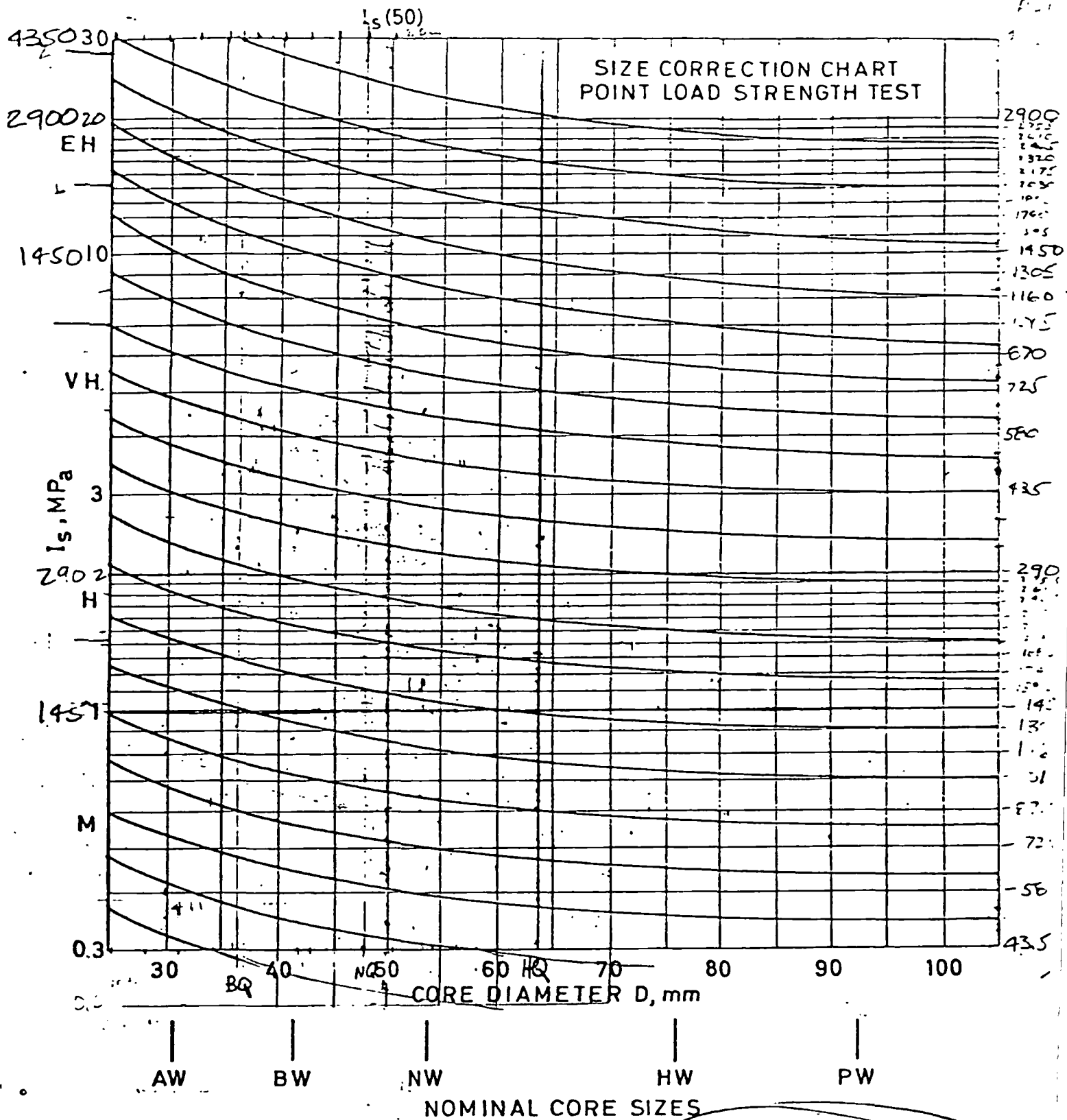


$$D = 50 \text{ mm}$$

$$\frac{D}{L} = 10 \text{ to } 14$$

Fig. 2 (c)  
Irregular lump test

Fig. 2



$1 \text{ MPa} = 145 \text{ psi}$

$1 \text{ psi} = 0.007 \text{ MPa}$

$1 \text{ Pa} = 0.007 \text{ psi} (0.069)$

**JOB NUMBER**

[illegible]

**Comments:**



**EWAS**

FIELD MANUAL FOR RECORDING  
DISCONTINUITY OBSERVATIONS

Prepared  
by  
PITEAU ASSOCIATES ENGINEERING LTD.

OCTOBER, 1985

## FIELD MANUAL FOR RECORDING DISCONTINUITY OBSERVATIONS

### INTRODUCTION

Stability of underground and surface rock excavations or natural slopes in rock is most often controlled by natural discontinuities in the rock mass.

Discontinuities may consist of bedding planes, joints, shears, faults, lithologic contacts, etc., which are often planes of low strength in a relatively strong medium. Recording of discontinuity observations by the techniques described herein serves to provide a data base for quantitative and statistical description of the rock mass. This classification provides the engineering geologist with a necessary tool for understanding the mechanics and kinematics of possible failures and is the basis for design of excavations and/or remedial measures.

Mapping of discontinuity information is recorded on a standard sheet which is formatted for easy computer input (see Fig. 1). Mapping is carried out along a fixed, straight line traverse on a rock exposure. A tape is usually attached to the rock surface at each end of a traverse. The ends of the traverse are later located by a survey of coordinates and elevation. By convention, the traverse proceeds from left to right along the exposure.

Each traverse is described in the first row of the recording sheet by naming the traverse, and by specifying the coordinates and elevation of the starting point, trend and plunge of the traverse alignment, the mapping system in use, length of the traverse and the number of observations made on the traverse.

Within a traverse, each discontinuity is described according to its position, rock type, rock hardness, structure type, orientation, infilling, continuity, spacing and number of structures if part of a set, water condition and surface characteristics. Each of these observations is described in detail below.

### SYMBOLS

Before undertaking a mapping project, a set of mnemonic symbols should be agreed upon to describe the structure, rock and infilling types. These can be added to

as the need arises during mapping. In the case of rock type, a three letter mnemonic code is normally used. Structural discontinuities are given a two letter code. Infillings are given a one letter code.

## UNITS

A consistent set of units must be used for describing traverse coordinates and traverse length as well as distance along the traverse to a structure. That is, if coordinates are entered in decimetres, so must length of traverse and distance. Structure length is usually, but not necessarily, entered in the same unit system. Depending on the structural geology of a particular site, it may be more convenient to use smaller units for gouge width, say centimetres or millimetres.

## BASIC EQUIPMENT

The basic equipment required for this mapping method is:

- (a) clino rule, Brunton compass or Clar compass for measuring structural attitudes
- (b) a tape at least 30m (100 ft.) long for locating structures between traverse stations
- (c) notebook and field recording data sheets
- (d) nails, flagging tape and spray paint for establishing and identifying traverse stations
- (e) Brunton compass for measuring traverse trend and plunge
- (f) rock hammer for lithologic and hardness classifications
- (g) large scale plan map of survey area for mapping basic structures in conjunction with the detailed mapping
- (h) basic geological survey equipment such as hand lens, magnet, pocket knife, acid, etc.
- (i) a camera to photograph rock exposures and structures of particular note.

## ESTABLISHING THE TRAVERSE

After a preliminary survey of the area, the traverse station is established at waist height or where convenient by driving a nail into a crack in the rock. The traverse is then identified using flagging tape and spray paint. A 30m (100 ft) tape is attached to the nail and stretched along the rock face, and a second traverse station is established at the end of the traverse. By convention, traverses should be set out from left to right, looking at the rock face, so that the traverse line is on the operator's left when looking from the start to the end of the traverse. Traverses should be well marked at each end with spray paint and flagging tape so that they can be readily recognized from some distance (i.e. across the pit) for purposes of correlation of structures between benches, and for field recognition by the survey crew who will pick up and locate the traverse stations on a plan drawing. Where possible, the traverses should be joined end to end to reduce the number of points surveyed and to avoid the possibility of missing important structural features. If two operators are mapping, they should generally attempt to alternate traverses along the bench faces to minimize any bias due to differences in mapping procedures.

## GENERAL TRAVERSE DATA

The top line of the field mapping sheet (see Fig. 1) contains data relevant to the entire traverse. Traverse data will relate to all subsequent data entered on the sheet. Each entry is described in detail below.

Traverse - Four spaces are provided for a unique traverse name to be coded in alpha and/or numeric symbols. Typical traverse names could be D001, D002, 2501, 2502, etc.

Northing, Easting and Elevation - Six spaces are provided for each of Northing and Easting, and five spaces for Elevation. These coordinates pertain to the location of the beginning of the traverse and can be entered in any convenient system (eg. - UTM coordinates, local property grid coordinates, etc.) using the same units as the distance column (see below). Usually, tenths of metres or tenths of feet would be appropriate.

Trend - Trend refers to the azimuth direction of the traverse from beginning to end, and is entered as a three digit bearing from  $000^{\circ}$  to  $360^{\circ}$  (i.e. north =  $000^{\circ}$  or  $360^{\circ}$ , south =  $180^{\circ}$ , east =  $090^{\circ}$ , etc.).

Plunge - Plunge refers to the slope of the traverse line and is entered as a two digit number from  $-90^{\circ}$  (vertically down) to  $00^{\circ}$  (horizontal) to  $+90^{\circ}$  (vertically up) (i.e. if the start of the traverse is higher than the end, the plunge should be entered as negative).

Reference (REF) - This refers to the mapping system in use and is entered as 1, 2 or 3, as described below.

Length - Four spaces are allotted for the total length of the traverse to be entered in the same unit system as the traverse coordinates.

Observations (OBS) - Two spaces are allotted for the total number of observations mapped on the traverse.

## MAPPING SYSTEMS

Three mapping systems are available which are based on the method by which the orientations of geological structures are mapped. Each system is described in the following:

Mapping System 1 - Dip direction is recorded in the azimuth columns as a three digit bearing from  $000^{\circ}$  to  $360^{\circ}$ . Dip is recorded as a two digit number from  $00^{\circ}$  to  $90^{\circ}$ . No entry under "DIR" is required. This type of mapping is normally conducted with a Clar compass or Breithaupt compass.

Mapping System 2 - Strike is recorded in the azimuth columns as a three digit number from  $000^{\circ}$  to  $180^{\circ}$ . Dip is recorded as a two digit number from  $00^{\circ}$  to  $90^{\circ}$ . Dip direction, "DIR" is recorded as NE, SE, SW or NW to indicate the quadrant towards which the structure dips. This type of mapping is normally conducted with a Brunton type compass.

Mapping System 3 - This system is designed for locations where a conventional compass is impractical due to magnetic interference. In this case a carpenter's angle rule (Clino Rule) is used for mapping. Azimuth is recorded as the clockwise angle ( $000^{\circ}$  to  $180^{\circ}$ ) between the trend direction of the traverse (i.e. looking along the traverse from start to finish) and the strike line of the discontinuity. Dip is recorded as above. Dip direction is recorded as positive (+) if the discontinuity dips towards the positive or forward direction of the traverse, and as negative (-) if the discontinuity dips towards the beginning or negative direction of the traverse.

An example of the use of the three systems is given in Fig. 2.

#### DISCONTINUITY DATA

The main body of the mapping sheet is for recording data pertaining to individual observations of structural discontinuities along the traverse. The operator's discretion must be used to discriminate between relevant and irrelevant structural geological features with respect to the nature of the project at hand. For example, in design of high rock slopes for open pit mining, a minimum structure size is usually specified (eg. 3m or 5m), as recording all fractures in a rock mass could be impractical. Further, structures less than this size would not be highly relevant to stability of slopes excavated in 15m or 30m high benches. However, an individual assessment must be made for each project and the operator must be cognizant of the scope of the project and use his/her discretion to collect the most relevant data.

Each line of the main body of the mapping sheet (Fig. 1) is for recording one discontinuity observation. Not all of the columns must be filled in for each entry. Those for which an entry is mandatory are marked with an asterisk (\*). Each individual column entry is discussed below.

#### Distance\*

Distance from the beginning of the traverse must be noted for each observation. Distance is recorded at the point where the projection of the observed discon-

tinuity intersects the tape. Units must be consistent with traverse coordinates in the first row of the sheet.

### Rock Type

The rock type is determined by conventional geological techniques. In all cases, the type of rock up traverse from the last geological feature observed is recorded using a three letter mnemonic as per examples given in Appendix A. Exposed rock further along the traverse is recorded with the next surface observation.

### Hardness

The rock hardness or consistency is determined by a series of simple mechanical tests using a rock hammer and pocket knife. Appropriate symbols and the methods by which hardness categories are determined are explained in Table I (after Jennings, 1968)<sup>1</sup>.

### Structure Type<sup>\*</sup>

The genetic type of geological structure observed is recorded as a two letter code, which can be changed to suit the particular project. Common geologic structures with typical codes are given in Appendix A.

### Azimuth, Dip and Direction<sup>\*</sup>

Any of the three systems described above can be used (see section on mapping systems), depending on the situation or preference of personnel involved. A number, corresponding to system 1, 2 or 3 is required under "REF" in the traverse data row (Row 1).

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1. Jennings, J.E., (1968). A preliminary theory for the stability of rock slopes based on wedge theory and using results of joint surveys. University of the Witwatersrand, Internal Report, unpublished.

### Infilling

Infilling is meant to include any materials that occur between the planes of any structural feature, regardless of the type. Infilling is thus taken to include materials derived from breakage of the country rock due to movements and chemical changes (i.e. alteration products) and foreign infilling materials deposited between the structural planes, such as calcite.

The type of joint infilling material is recorded using single letter mnemonics in the three columns provided (see Fig. 1). The most abundant type of infilling should be recorded in the right hand column. Some typical infillings are given in Appendix A.

### Length

The length or size of a discontinuity is determined by estimating or measuring the actual trace length which is visible on either the surface outcrop or cut face.

### Spacing and Replication of Discontinuity Sets

In cases where several discontinuities of similar orientation, length and surface characteristics are identified, the spacing (SPCG) and the number (N/S) of discontinuities are recorded in the appropriate columns to facilitate mapping. The orientation of the set is recorded as the apparent average orientation of the discontinuities observed.

In general a number of structures (N/S) in excess of eight structures should not be recorded, as high replication tends to result in biasing and distortion of the lower hemisphere equal area projections. In a case where more than eight structures exist, more than one measured observation is used to represent the group.

### End Conditions

Additional information on continuity may be recorded according to the number of degrees of uncertainty of the trace length of the discontinuity. If one end of

the structure is continuous upwards or downwards out of the rock face being considered, there is one degree of uncertainty and "ends" (E) is booked as 1; if both ends are continuous out of the face, "ends" is booked as 2; if both ends can be seen, there is no uncertainty regarding the length of the structure and "ends" is booked as zero or left blank.

### Groundwater

The presence or absence of water in either joint infilling materials or in the structural plane in general may be recorded in the column headed by "W", based on the following five categorizations:

<u>Category</u>	<u>Degree of Water</u>
1	The discontinuity is tight; water flow along it does not appear possible.
2	The discontinuity is dry with evidence of water flow, rust staining of discontinuity surface, etc.
3	The discontinuity is damp but no free water is present.
4	The discontinuity shows seepage, occasional drops of water, no continuous flow.
5	The discontinuity shows a continuous flow of water.

### Roughness

Roughness of the joint surface may be recorded on a five-finger scale. The five categories of roughness are as follows:

<u>Category</u>	<u>Description</u>
1	Slickensides or polished
2	Smooth
3	Defined ridges
4	Small steps
5	Very rough

### Gouge Width

Thickness of the discontinuity or gouge infilling is taken as the width of that material between sound intact rock. Thickness may be recorded in convenient length units and on a categorized scale, as follows:

<u>Category</u>	<u>Thickness</u>
A	0.00
B	0.00 - 2.5mm
C	2.5mm - 5.0mm
D	5mm - 10mm
E	1cm - 2cm
F	2cm - 5cm

Thicknesses greater than 5cm should be recorded to the nearest 0.1m eg 01, 02. If gouge width is greater than 9.9m, a separate rock type should be recorded. Depending on site conditions it may be desirable to record gouge width to the nearest 0.01m in which case a separate rock type would be required for widths greater than 1m.

### Waves

Waviness of the structural plane may be measured by placing a clino-rule in the hollow of the wave and recording the inter-limb angle (ILA) that occurs between the legs of the clino-rule. The legs of the clino-rule should be fully opened when this is measured.

### **COMPILATION OF PLAN MAP**

In addition to completing the field data sheets as discussed above, it is also necessary to prepare a field geological map of the site after each traverse is completed. This plan should consist of a topographic plan or a plan of the pit benches or underground openings. The following information should be compiled in the field and transferred to the plan map:

- (i) Location of traverse stations.
- (ii) Location of major structures, geological boundaries, rock types, etc.
- (iii) Interpretation of structures between traverses or from one traverse to traverses or benches above and below the mapped traverses.

(v) Important engineering geology features, such as:

- weathered or broken areas
- rockfalls, failures, etc.

This plan will be prepared during mapping and information transferred to a base map as surveying information becomes available.

Eventually this information will comprise a complete engineering geology plan of the site suitable for inclusion in an engineering report.

#### SUMMARY

The mapping system has been designed to be extremely flexible so that the parameters, units, etc. can be modified to suit site conditions. Therefore, for any particular project site, a detailed engineering geology site report should be prepared to fully describe the symbols used and actual meaning of the various parameters and codes used on the data sheets.

## APPENDIX A

### Examples of Typical Structure Types, Rock Types and Infilling Types with Definitions and Appropriate Mnemonic Symbols\*

#### STRUCTURE

**Axial Plane (AP)** - The surface joining the lines of maximum curvature on successive layers of a fold. Axial planes are imaginary planes which define the shape of folds and do not represent any physical discontinuity in the rock mass.

**Bedding (BG)** - Regular layering in sedimentary rocks marking lithological contacts.

**Cleavage (CV)** - Closely spaced parallel surfaces of fissility in rock not parallel to lithologic contacts.

**Contact (CN)** - Surface between two rock types.

**Dyke (DK)** - A sheet-like body of igneous rock that cuts across the structure in adjacent older rocks which it entered while in a molten condition.

**Fault (FL)** - Surface of shear recognizable either by the displacement of another surface that crosses it, or by striated slickensides on the surface. Faults thus include all "shears". Faults can be classified by the direction of slip of the fault block which rests on the fault plane (the hanging wall block). Refer to slip and separation under type of lineation. For descriptive terms use fault breccia (FB), slickensides (SK), striae (ST), gouge (GO), mylonite (MO), fault zone (FZ), etc.

**Foliation (FN)** - Surface parallel to compositional contacts in a metamorphic rock.

**Gneissosity (GS)** - Surface parallel to lithological layering in metamorphic rocks.

**Joint (JN)** - Fracture in rock mass along which there has been no identifiable displacement. For descriptive and/or analysis purposes it may prove advantageous to record the genetic type if known. Some of these which could be considered are tectonic joint (TJ), bedding joint (BJ), columnar joint (CJ), and sheet joint (SJ).

**Joint Set (JS)** - Recognized set of joints which have common attitude and length. The spacing and frequency of these joints is recorded. For descriptive purposes, if these joint sets are tending to be uniformly related, they could be referred to as a joint system (JY) and, when they persist over great areas, we designate this jointing as the regional joint pattern (RJ).

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\* Note: Symbols are devised using standard mnemonic codes. However, symbols used on a particular project should be devised to suit that project and be consistent for all symbols used on the project.

Schistosity (SC) - Surface of easy splitting in a metamorphic rock defined by the preferred orientation of metamorphic minerals.

Shear (SR) - Surface of shear without recognizable displacement. It can be recognized by slickensides, polishing or slickness of the surface or striations on the surface.

Sill (SL) - A tabular body of igneous rock that has been injected while molten between layers of sedimentary rocks or along the foliation planes of metamorphic rocks.

Tension Crack (TC) - A tension feature which is open and planar in form; such features could be tension cracks at slope crests or naturally occurring discontinuities which have opened.

Unconformity (UC) - Eroded surface covered by sedimentary rock.

Vein (VN) - Fracture in rock with a filling apparently injected at the time the fracture formed.

### ROCK TYPES

#### Intrusive Rocks

Granite	GRT
Granodiorite	GDR
Aplite	APT
Pegmatite	PGT
Diorite	DRT
Quartz Diorite.	QDT

#### Volcanic Rocks

Andesite	ADT
Rhyolite	RLT
Tuff	TFF
Basalt	BST

#### Sedimentary Rocks

Conglomerate	CGT
Coarse Sandstone	CSD
Medium Sandstone	MSD
Fine Sandstone	FSD
Silty Sandstone	SSD
Sandy Siltstone	SSL
Siltstone	SSH
Silty Shale	SHL
Claystone	CLT
Coal	COL
Carbonaceous Claystone	CCL
Carbonaceous Shale	CSH

#### Metamorphic Rocks

Gneiss	GNS
Quartzite	QZT
Schist	SHT
Muscovite Schist	MST
Biotite Schist	BST
Quartz Biotite Schist	QBS
Garnet Schist	GST
Phyllite	PHT

## INFILLING

- Air (A) - total void exists between the walls of the plane
- Soil - Clay (C), Sand (S)
- Calcite (Z)
- Detritus (D) - debris washed into an open fracture
- Evaporites (E) - gypsum, halite, anhydrite
- Feldspar (F) - hard, often pink, insoluble, good cleavages, easily weathered
- Gouge (G) - wall rock is often ground up by movements along a fault zone. Gouge is the result of the accelerated weathering of the resulting fine grained materials; it is generally a green clay.
- Breccia (B) - consolidated angular rock fragments larger than sand grains resulting from fault movement.
- Ore (O) - valuable
- Quartz (Q) - hard, white and insoluble

QUALITATIVE & QUANTITATIVE EXPRESSIONS  
FOR CONSISTENCY OF COHESIVE SOIL AND ROCK\*

HARDNESS	CONSISTENCY	FIELD IDENTIFICATION	APPROXIMATE RANGE OF UNCONFINED COMPRESSIVE STRENGTH	
			MPa	p.s.f.
S1	very soft soil	Easily penetrated several inches by fist; shows distinct heel marks.	<0.025	<3.5
S2	soft soil	Easily penetrated several inches by thumb; faint heel marks.	0.025 - 0.05	3.5 - 7
S3	firm soil	Can be penetrated by thumb with moderate effort; difficult to cut with hand spade.	0.05 - 0.10	7 - 14
S4	stiff soil	Readily indented by thumb but penetrated only with great effort; cannot be cut with hand spade.	0.1 - 0.2	14 - 28
S5	very stiff soil	Readily indented by thumbnail; requires pneumatic spade for excavation.	0.20 - 0.4	28 - 56
S6	hard soil	Indented with difficulty by thumbnail.	>0.4	>56
R0	extremely soft rock	Indented by thumbnail.	0.2 - 0.7	28 - 100
R1	very soft rock	Crumbles under firm blows with point of geological pick; can be peeled by a pocket knife.	0.7 - 7.0	100 - 1,000
R2	soft rock	Can be peeled by a pocket knife with difficulty; shallow indentations made by firm blow of geological pick.	7.0 - 28	1,000 - 4,000
R3	average rock	Cannot be scraped or peeled with a pocket knife; specimen can be fractured with single firm blow of hammer end of geological pick.	28 - 56	4,000 - 8,000
R4	hard rock	Specimen requires more than one blow with hammer end of geological pick to fracture it.	56 - 112	8,000 - 16,000
R5	very hard rock	Specimen requires many blows of hammer end of geological pick to fracture it.	112 - 224	16,000 - 32,000
R6	extremely hard rock	Specimen can only be chipped with geological pick.	>224	>32,000

\* Modified Rock Hardness Classification

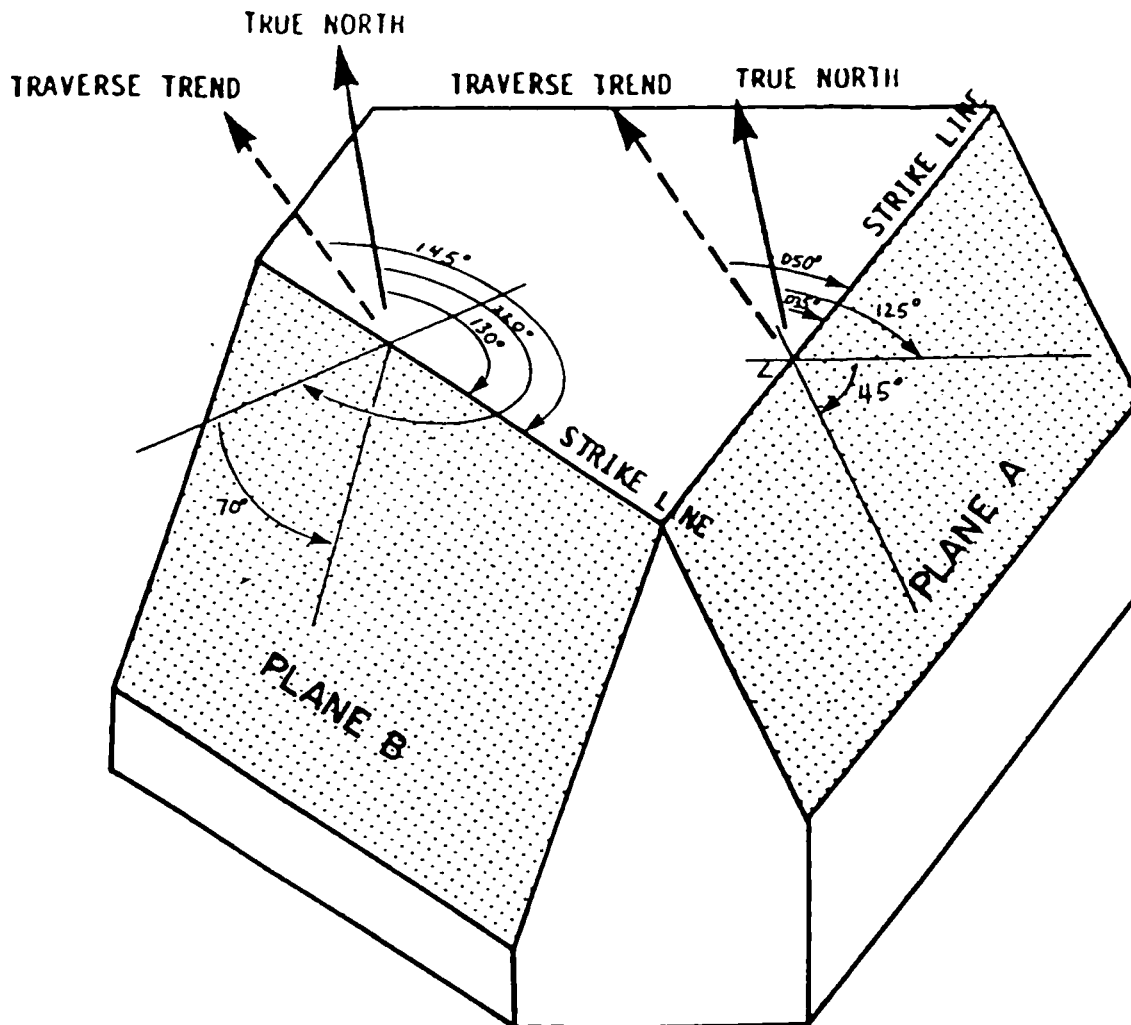
- S1 to S6 Modified after Terzaghi, K. and Peck, R.B., 1967. "Soil Mechanics in Engineering Practice, 2nd Edition, John Wiley and Sons Inc., New York. p.30.
- R1 to R5 Modified after Piteau, D.R., 1970. "Geological Factors Significant to the Stability of Slopes Cut in Rock" in Planning Open Pit Mines, Van Rensburg Ed. Aug. 29-Sept. 4, 1970. Balkema. p.51 and 68.

SITE \_\_\_\_\_ LOCATION \_\_\_\_\_ SYSTEM \_\_\_\_\_ DATE \_\_\_\_\_ NAME \_\_\_\_\_

[illegible]

DISTANCE	ROCK	HDN	STR	AZIMUTH	DIP	DIR	INFILLING	LENGTH	SPCG	E	W	R	GOUGE WIDTH	WAVES	N/S	COMMENTS
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JOB NUMBER



	PLANE A			PLANE B		
	AZIMUTH	DIP	DIR	AZIMUTH	DIP	DIR
SYSTEM 1	125	45		220	70	
SYSTEM 2	035	45	<del>SSE</del> <sup>130</sup>	<del>035</del>	70	<del>SSE</del>
SYSTEM 3	<del>050</del>	45	-	<del>050</del> <sup>195</sup>	70	-



**PITEAU ASSOCIATES**  
 GEOTECHNICAL CONSULTANTS  
 VANCOUVER CALGARY

BLOCK DIAGRAM ILLUSTRATION OF  
 MAPPING SYSTEMS

BY: <i>BST</i>	DATE: JULY 85
APPROVED:	DWG:

**JOHN DUFF ERICKSON**  
2958 TOMAHAWK DRIVE  
RAPID CITY, SOUTH DAKOTA 57702

**Mine Planning and Geotechnical Assessment  
of  
Sunday and Dakota Maid Pits  
for  
Gilt Edge Mining Incorporated**

**Introduction**

This report was prepared for Gilt Edge Mining Incorporated as a technical assessment of the mining plans for the proposed reactivation of the Gilt Edge Mine.

The scope of the work included a review of mining plans level by level, location of the final pit limit topography and the stability of the proposed 45 degree final pit slopes.

**Action**

A series of mine level plans for each 20 foot elevation interval showing the location of the ore blocks and the pit limits down to the 5300 level were reviewed in detail. Also reviewed were the plans of the final pit topography designed at a maximum pit slope angle of 45 degrees.

On 24 August 1986, the Gilt Edge mine site was visited with Dr. Z. Hladysz to inspect the exposed walls of the Sunday and Dakota Maid pits. Also a reconnaissance of the underground workings in the Sunday pit area was made.

A sample of wall rock from the underground workings was taken. In addition, several selected cores were taken from the core drilled to evaluate the property. This material was tested by Dr. Z. Hladysz. His report is attached.

**Conclusions**

The plans for mining the Sunday and Dakota Maid pit areas are typical of the surface mining method used to mine an ore deposit of the type found at Gilt Edge. Low grade ore occurring near the surface and extending vertically downward dictate that surface mining is the preferred method of extraction.

The basic economic reality of mining a deposit like Gilt Edge is that the final pit slope should be as steep as safely possible for maximum recovery of the natural resource. To achieve less would result in the wasting of the natural resource. Such material is rarely economical to recover at a later date.

Evaluation of the Gilt Edge geotechnical parameters was relatively straight forward because of the exposed rock faces and structure. The high walls in the old pits are still standing stable after many years of exposure to the elements.

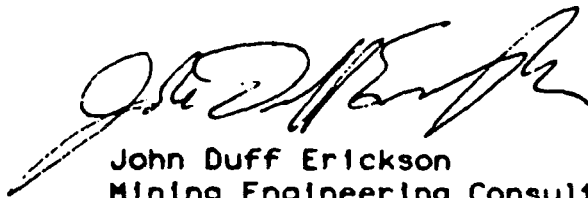
The underground openings examined were structurally sound and intact after a long period of standing unsupported. Of particular interest was the old underground hoist station that had the sheave wheel located in unsupported rock. Again the rock in this area has remained stable over a long period of time. Next to the Sunday pit a large unsupported open slope was observed still structurally intact.

Ground water and hydraulic pore pressure does not appear to be a factor of concern in the Gilt Edge area rock mass.

From these observations it is concluded that 45 degrees is a conservative overall final pit slope angle. The faces of the intermediate benches will stand at slopes much steeper than 45 degrees. The exact stable slope angle of each intermediate face will be dependent upon the structure and geology of the rock face.

Fractures and joint patterns in some of the rock may cause localized toppling failures. These will be easily contained by the intermediate catch benches and will not effect the overall long term stability of the reclaimed high walls.

The mining plan proposed by Gilt Edge Mining, Incorporated is considered to be the best alternative and should be accepted.



John Duff Erickson  
Mining Engineering Consultant  
30 August 1986

## Gilt Edge Mine Rock Strength Test Results

Preliminary estimation of the strength of the principal rock (porphyry) to be encountered in the high wall of the Gilt Edge mine was determined using the portable rock strength tester. Rock material tested included a sample taken from the wall of the underground workings and several cores available from the previous exploratory drilling.

Average uniaxial compressive strengths of the porphyry samples are as follows:

- A. Wall sample
  - Uniaxial compressive strength: 10744 psi
  - Standard deviation: 1759 psi
  - Coefficient of variation: 16 %
  
- B. Drill cores
  - Uniaxial compressive strength: 11485 psi
  - Standard deviation: 1272 psi
  - Coefficient of variation: 11 %

### Conclusion

The results of the preliminary tests show that the porphyry can be classified as a strong rock. If such a rock does not contain any discontinuities or planes of weakness it will provide long term stability of rock structures on the surface and underground.

  
Dr. Z. Hladysz  
Associate Professor Mining Engineering  
South Dakota School of Mines  
and Technology